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GEOLOGY

The Proterozoic Pogor'uy Formation of Yenisei Ridge: Age and Provenance Sources According to U/Pb Dating of Detrital Zircons

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Abstract—The results of U–Pb-isotopic dating of detrital zircons from sandstones of the Proterozoic Pogor'uy Formation, occurring to the north and south of the East Angara block of Yenisei Ridge, are presented. The sandstones of the northern part of the East Angara block are dominated by Archean and Paleoproterozoic populations of detrital zircons, while the samples from the southern part of the East Angara block have been revealed up to 25% of Mesoproterozoic age grains. The detrital zircon ages allow limiting the maximum sedimentary age of the Pogor'uy Fm. and the entire interval of its formation to 1.2–0.9 Ga. The paleogeographic features of the Pogor'uy Fm. deposition in the context of the existing opinions on the location of Siberia within the Rodinia supercontinent were examined.

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The Yenisei Ridge (YR) is the relic of the largest Proterozoic orogen [1, 2], and one of the key structures for deciphering the Late Precambrian geodynamic evolution of the western margin of the Siberian Craton (SC). Traditionally the Yenisei Ridge is subdivided into the northern (Trans–Angara) and southern (Angara–Kan) parts [1, 3]. From west to east, the Trans–Angara encompasses the Isakov, Central Angara, and East Angara blocks [1]. The latter is usually regarded as a deformed fragment of the Late Precambrian passive margin of Siberia. The object of our study is sandstone of a key section of the Pogor'uy Formation of the Sukhopit Group occurring in the Irkineeva uplift, located in the southern part of the East Angara block (Fig. 1).

The Pogor'uy Formation is the upper element of a large prograding siliciclastic sequence [4], conformably overlain by carbonate sedimentary rocks (the Kartochka Fm. and others). The Pogor'uy Formation begins the Upper Precambrian section of the Irkineeva uplift. Its contact with older formations is not exposed. In the study area, the Pogor'uy Formation (at least 1 km thick) contains siliciclastic tempestite and less common turbidite. The presence of tempestites containing textures generated by storms (hummocky cross–stratification) and the transition to the stromatolite carbonate facies upwards through the section indicate that deposition of sediments of the Pogor'uy Formation occurred mainly in the open shelf environments of the SC. K–Ar dating of glauconite from the sandstones of the Pogor'uy Formation (~1110 Ma) [5, 6], as well as chemostratigraphic characteristics of the conformably overlaying carbonates of the Irkineeva uplift [7, 8], indicates that the deposits of the Pogor'uy Formation were accumulated at the end of the Mesoproterozoic and Early Neoproterozoic.

Westwards, inside the Central Angara zone, sediments traditionally ascribed to the Sukhopit Group metamorphosed under conditions up to greenschist facies are intruded by the Teya granitoid complex [9], dated by U–Pb to about 865 Ma [3] or to about 1100 and 865 Ma [9]. Since some researchers consider the Central Angara zone to represent a separate terrain, located at the time of the Teya granite intrusion at a distance from Siberia [1], the younger age limit of the Pogor'uy Formation estimated by the cross-cutting granite is controversial.

U–Pb dates of detrital zircons were obtained by us from three samples of the Pogor'uy Formation sandstones, one of which (K 14-014) was collected in the

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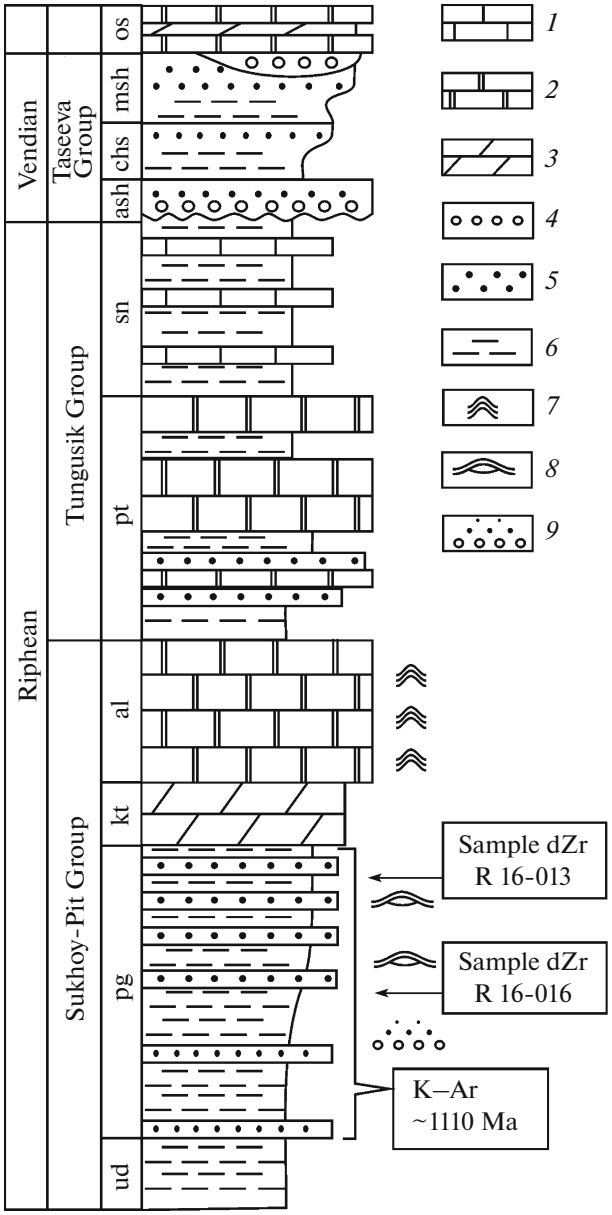

Fig. 1. Schematic stratigraphic section of the Upper Precambrian formations of the Irkineev uplift. (*1*) Limestone, (*2*) dolomite, (*3*) dolomite and calc marls, (*4*) conglomerate, (*5*) sandstone, (*6*) siltstone and mudstone; (*7–9*) structural and textural features of rocks (*7*) stromatolite buildups (bioherms); (*8*) hummocky cross–stratification; (*9*) turbidite gradational bedding. Abbreviations of formations in the stratigraphic column: Ud, Uderei; pg, Pogor'uy; kt, Formation of Kartochka crag; al, Aladin; pt, Potoskui; sn, Shuntar; ash, Aleshino; chs, Chistyakov; msh, Moshakovo; os, Ostrov Formation (Cambrian).

northern region of Trans–Angara (see [10]), and the other two, the results of which are discussed below, are taken from the south of the Trans–Angara region. New samples R 15-013 and R 15-016 were collected in a typical section of the Pogor'uy Formation on the left bank of the Irkineeva River, 1 and 2 km downstream from the Kartochka crag, respectively. Sample R 15-016 was collected from the middle, and sample R 15-013 came from the upper subformation of the Pogor'uy Formation; the stratigraphic interval between sampling points is 870 m.

U–Pb analyses of detrital zircons were carried out at the University of Newcastle (Australia); the technical details on the equipment and methods were given earlier [10]. The acquired results on samples K 14-014, R 15–013, and R 15-016 are shown in Fig. 2.

Among the detrital zircons separated from sample K 14-014, two main populations have been revealed (Fig. 2): the Archean (3.0–2.5 Ga) and Paleoproterozoic (2.1–1.8 Ga), with the majority of grains having ages of about 1.9 Ga. Notably, there are no grains with ages in the 2.2–2.4 Ga interval, and only one Mesoproterozoic zircon has been found. The three youngest grains were dated to 1596 ± 53, 1823 ± 43, and 1838 ± 54 Ma.

The detrital zircons age distributions in samples R 15-013 and R 15–016 (Fig. 2) have an obvious similarity, confirmed by the K–S test results (Table 1). In sample R 15-013, the Mesoproterozoic zircons constitute 12% of the population; Palaeoproterozoic, 67%; and Archaean, 21%, while in sample R 15-016, these values are 25%, 60%, and 40%, respectively. Thus, the maxima of the probability density curves (PDF) at ages of 2675, 1855, 1483, and 1468 Ma for both samples coincide within the error limits (Fig. 2). The zircon populations from both samples include both euhedral (about 60% in sample R 15–013; about 30% in sample R 15-016) zonal crystals, and rounded grains without oscillatory zoning; there is no correlation between the zircon morphology and their U–Pb ages. The weighted average U–Pb age of the three youngest zircons in the sandstone samples from the middle and upper subformations of the Pogor'uy Formation is 1191 ± 49 Ma (MSWD = 0.6) and 1140 ± 61 Ma (MSWD = 0.12), respectively. The dates obtained are the new maximum limit to the time of the beginning of accumulation of the sediments in the middle subformation of the Pogor'uy Formation in the southern part of the East Angara block of the Trans–Angara. Therefore, taking into account all the available data, the accumulation time of the Pogor'uy Formation remains limited to a very wide time interval (between 1.2 and 0.9 Ga).

The age spectra of detrital zircons from the Pogor'uy Formation sandstones from the north and south of the East Angara block of the Trans–Angara have a significant qualitative difference (Fig. 2). In the south, a significant proportion of Mesoproterozoic (1600–1150 Ma) detrital zircons has been revealed, producing the detrital zircon signal similar to that found in similarly aged sandstones of Sette-Daban and Arctic Canada (Fig. 2) [11, 12]. There are no zircon grains with those ages in the Pogor'uy Formation sandstones in the northern part of the East Angara

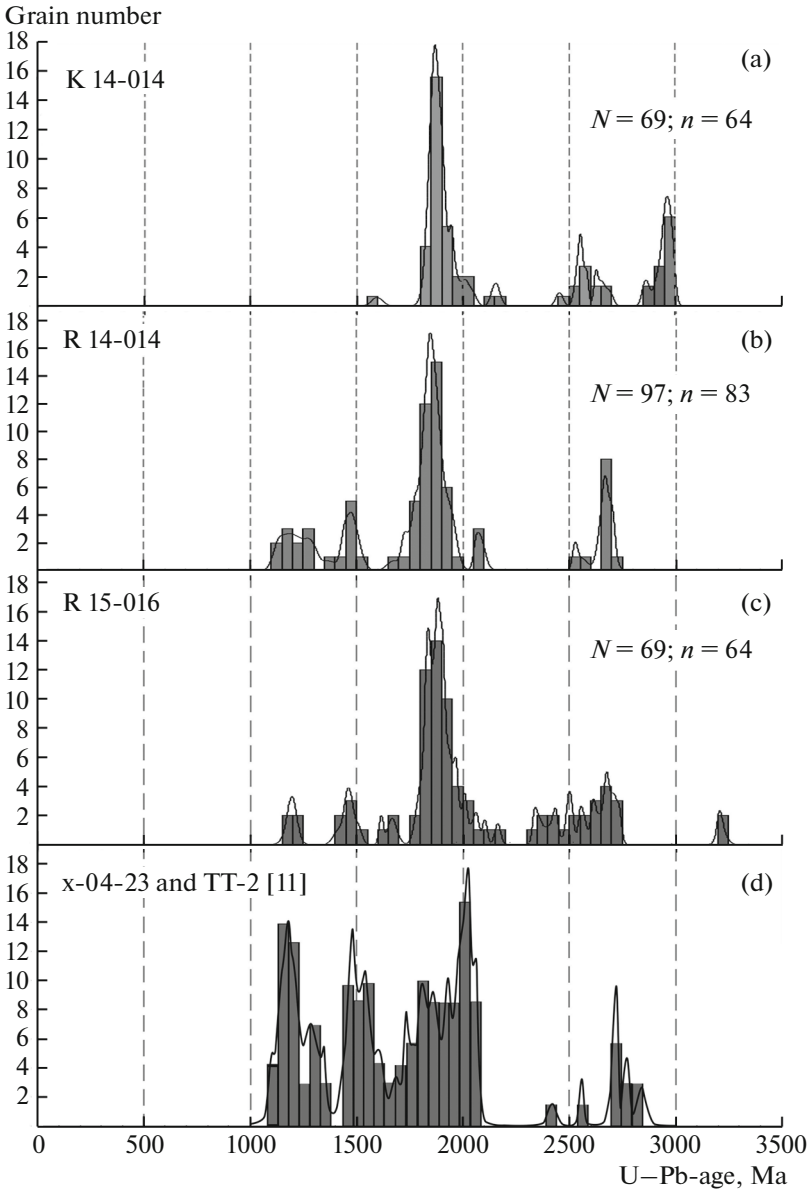

Fig. 2. Age distribution of detrital zircons from sandstones ascribed to the Kerpyl Riphean horizon: the Pogor'uy Formation of the East Angara block of the Trans–Angara part of Yenisei Ridge (a–c, present study) and sandstones of the Sette–Daban ridge (southeastern folded periphery of the Siberian platform (d, from [11]): *N*, total number of grains analyzed, *n* is the number of grains with a <10% discordance.

block. It should be noted that basement complexes of the Mesoproterozoic age, which could have provided detrital zircons to the west of the Siberian platform, are not common, and, therefore, zircons with such ages are exotic for the SC. The older intervals of the detrital zircons age spectrum from the Pogor'uy sandstones of the north and south of the East Angara block of the Trans–Angara are identical both between each other and with an age distribution spectrum of zircons from igneous rocks of the SC basement [10]. This confirms the assumption of deposition of the Pogor'uy Formation at a passive continental margin of the SC [13, etc.], mainly through accumulation of erosion products of Archean–Paleoproterozoic complexes of the Siberian Craton.

The revealed features of the detrital zircon age spectra from the Pogor'uy Formation sandstones of

Table 1. Results of K–S tests

	K 14-014	R 15-016	R 15-015
K 14-014		0.158	0.000
R 15-016	0.158		0.070
R 15-015	0.000	0.070	

the YR can be explained on the basis of well-known paleocontinent reconstructions. At the end of the Mesoproterozoic, the SC was a part of the Rodinia supercontinent, with its southern edge (here and below in present-day coordinates) adjacent to the northern edge of Laurentia, where the Mesoproterozoic magmatic complexes occur widely [e.g., 12, 14]. Most likely, the Mesoproterozoic detrital zircons could have been supplied into the sedimentation region that existed within the modern YR, between 1.2 and 0.9 Ga, directly from the Laurentia Craton, as is assumed for the closely aged Sette–Daban sandstones [12]. Thus, the qualitative differences in the detrital zircon age spectra from the Pogor'uy Formation sandstones of the southern and northern parts of the East Angara block of Trans–Angara can be explained by the location of these parts on opposite sides of the Irkineeva–Kotui aulacogen mouth [15], which served as a barrier for transportation of the Laurentic siliciclastics northwards along the western margin of Siberia. Definition of the exact location of the Mesoproterozoic detrital zircon provenance to the Pogor'uy Formation sandstones requires additional study.

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